Technical Diagnostics of Industrial Double Twist Twinner Machine for Data Cables

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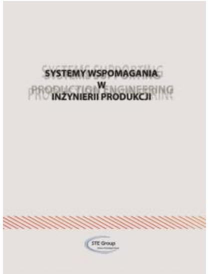

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Abstract: The presented article focuses on the diagnostic measurement and evaluation of vibrations of equipment used for data-cable twisted pairing manufacture. A short description of the process of the data cables manufacturing process to which the diagnosed device belongs is provided and the qualitative parameters of the data cables are mentioned. The experimental part is devoted to the experimental diagnostics of the given system in order to locate and identify the possible reason for the occurrence of the parameter´s critical value of the loss of the data cable. When deterioration of electric properties was detected, monitoring the basic oscillation characteristics has been deployed as the key tool to detecting damaged machine parts, and avoiding quality deterioration of the products in the manufacturing process. Finally, the quality of the paired cables after the repair has been confirmed by measurements verifying the efficiency of the measures performed

Keywords: vibrodiagnostics, maintenance, twisted pair cables, return loss, cable fault

INTRODUCTION

In the industrial practice, the deterioration of machine parts is a very common problem, which causes a reduction in the quality of the production outputs and problems with the machinery operation, along with deteriorated efficiency and of work environmental level, including the safety issues [1, 2].

There are several methods and procedures for detecting a malfunction or impending equipment failure. One of these methods is vibration diagnostics of machines and equipment, which deals with monitoring and evaluation of machine condition based on vibration measurements and analysis [3, 4]. Non-destructive diagnostic methods evaluate the real state of the device and the wear of its parts. Wear is manifested by increased values of the basic parameters of vibration. Increased vibrations negatively affect the functionality and correct operation of the machine, which causes significant problems. The aim of vibration diagnostics is therefore to find the causes of these vibrations. Therefore, vibration measurement belongs among the most effective tools for securing the conditions for proper and smooth operation of industrial machinery [5, 6, 7].

Maintenance is a combination of all technical, administrative, and managerial activities performed during the life cycle of the machine. The aim of these activities is to keep the machinery in condition, or to return it to a condition in which it can

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perform the required functions, considering optimal costs and quality, safety and environmental requirements. The main technical activities of maintenance include cleaning, lubrication, adjusting machines and performing repairs and reconstructions [8, 9, 10].

Maintenance according to technical condition consists in monitoring and trend evaluation of wear of a component or other characteristic related to wear. Maintenance intervention is performed only after finding out the actual condition of technical equipment, using one of the methods of technical diagnostics [11, 12, 13, 14]. The main advantage is that the equipment is taken out of operation only if the deteriorating condition of the equipment requires it. Parts are only replaced if they have reached the damage stage or have exceeded the permissible tolerances. The disadvantage is the initial costs of providing diagnostic equipment and training the operator.

The main aim of this work is diagnostics of the shielded twisted pair cables. The practical solution of the task consists of a description of vibrodiagnostic measurement on a selected group pairer, model GTSD 560N-4-4M. The purpose of this measurement is to try to locate and identify the cause of the critical value of the return parameter. Special attention is paid to the specific vibration parameters measured using the standard types of vibration sensors, based on vibrodiagnostic measurement in order to:

1. Locate and identify the possible cause of the critical value of return losses in the data cable production process.
2. Verify that the maintenance of the problem site helped to solve the problem with the loss parameter.

The conclusion of this section is to verify whether the maintenance of the diagnosed sites eliminated the problem with the monitored parameter.

DATA CABLE PRODUCTION PROCESS

Data cables are used for signal conduction, usually with low energy (10^{-6} W), at frequencies up to 108 Hz. Since only very low electric currents pass through these conductors, the diameter of the cores usually does not exceed 1 mm. Their use is related to the transmitted frequency, the higher the higher the requirements for longitudinal electrical homogeneity. The requirements regarding the length of the cable route are also growing [15, 16]. The most common type of data cable is the so-called a twisted pair whose cores are twisted into precisely defined twisted pairs that form the core of the cable.

The production of data cables starts with the cold processing of copper wire on wire drawing machine (Fig. 1). The wire is drawn on drawing discs with an ever-decreasing diameter until the wire reaches the desired diameter, belonging into one of the groups:

- coarse draws – wires with diameter from 1 mm to 4.5 mm;
- medium draws – 0.1-1.8 mm;
- fine draws – 0.01-0.25 mm.

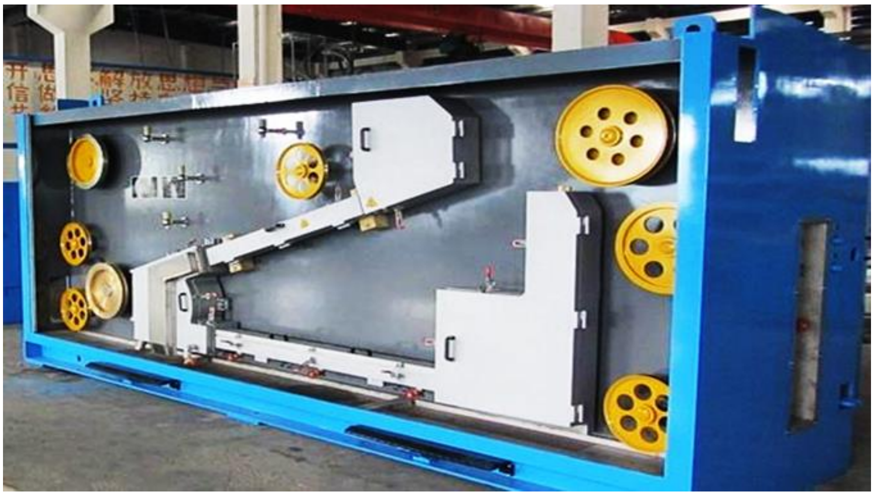

Fig. 1 Wire drawing machine

After drawing the wire, the copper is extremely fragile and can easily break when bending. Another operation is therefore the annealing of the wire, either continuously or in furnaces. In the furnaces, the whole coils of wire are annealed at once, while during continuous annealing, a high current is released into the wire by means of contact rollers, which heat the wire to the annealing temperature. By annealing, the internal stresses induced by mechanical processing are reduced and copper wire becomes soft and flexible.

Another input material that completes the cable is core insulation. The core is coated with an insulating material that forms a core or an insulated conductor from the core. In the so-called extruders, molten plastic is applied to the core at high temperature. In the extruder, the plastics are either pre-painted according to the standards directly into the mixture, sprayed onto the core, or the core is dyed using a co-extruder with a special extrusion head, the so-called spraying, when a thin layer of pre-painted mixture is sprayed on the finished colourless insulation. After the insulation is applied, the insulated conductor is wound on a coil and ready for group pairing.

During the group pairing process, the insulated cores are twisted into pairs so that the length of the screw within a given pair is always the same. However, each pair has its own unique screw length, so there are different twisted pairs in the same cable. The greater the number of twists per unit length, the better quality of the cable is achieved. The twisting of the individual pairs of conductors helps to attenuate mutual crosstalk and noise from the outside environment and at the same time prevents electromagnetic interference [17, 18]. Twisted cores have a higher resistance to the corresponding type of interference, because the induced voltage is cancelled out by the opposite phase. For higher cable categories, twisting alone does not provide sufficient properties, thus the pairs are additionally shielded along the entire length with PET foil and an aluminium layer. The process of shielding the twisted pairs is shown in Fig. 2.

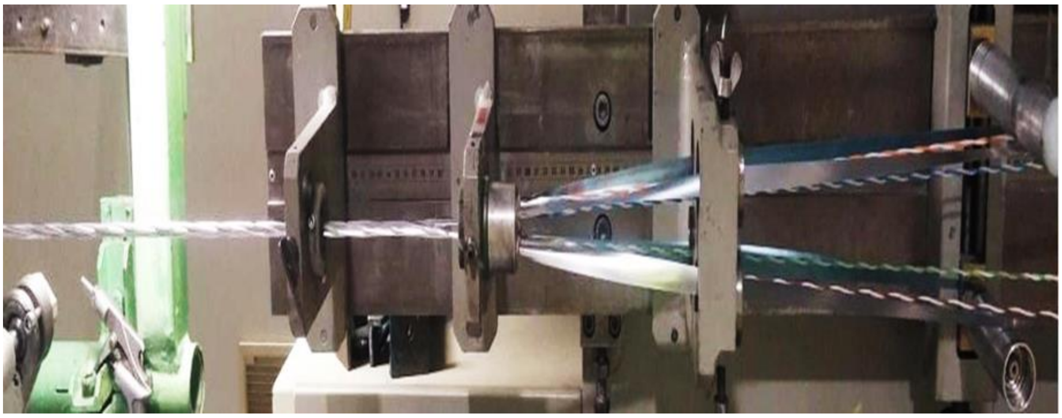

Fig. 2 PET foil shielding

Group pairing is a penultimate manufacturing operation. After that, in the last step, it is necessary to pass the complete cable construction through the extruder for the last time and apply a cable sheath to that. The purpose of the sheath is to hold the cable structure conjointly and protect it from adverse external influences, such as:

- humidity,
- mechanical damage,
- electromagnetic field,
- chemicals,
- heat or fire,
- UV radiation.

BASIC DATA CABLE QUALITATIVE HIGH-FREQUENCY PARAMETERS

Measuring electrical parameters is essential for the verification of manufactured cable functionality. Precision measurement determines whether all the requirements are met as defined in the standards to ensure reliable operation in the required applications [19, 20]. High-frequency and low-frequency parameters are distinguished during the verification.

Return Loss (RL) – back reflection is a phenomenon that is given by a varying impedance inside the cable. The principle of back reflection is a partial return of the energy under transmission back to the sender. Thus, the reflection negatively affects the signal quality since the signal can be disturbed by this reflection. The unit of RL is the decibel (dB). The higher the RL value, the less energy is returned to the transmitter and the less error-prone the cable is. The values for measuring back losses are usually in the range from 0 dB to 60 dB, with 0 dB corresponding to a short circuit and 60 dB representing an ideal value.

Most common back reflections are caused by a damaged or poor-quality cable where the impedance is varying along its length [21]. Another source is caused by irregular twisting. The principle of the return loss is shown in Fig. 3.

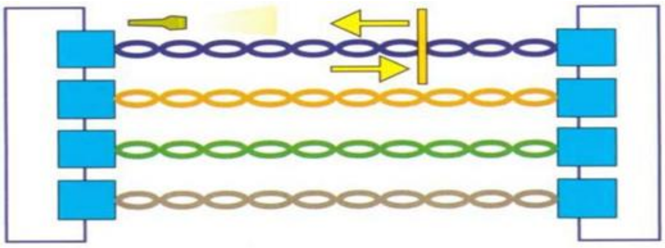

Fig. 3 Return loss principle

Source: [22]

Near End Attenuation (NEXT) – expresses the extent to which a signal transmitted by one pair is affected by an adjacent pair of metallic cables and is measured in dB. Interference from a neighboring pair can distort the useful signal to such an extent that it will be unreadable by the active device (Fig. 4). NEXT is measured at the near end, i.e., on the signal transmission side.

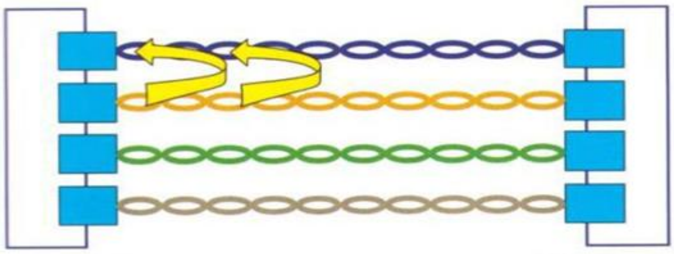

Fig. 4 Near End Attenuation principle

Source: [22]

Far End Attenuation (FEXT) – similar parameter as NEXT, except measured at the far end of the cable. FEXT is a much more important parameter of the data cable because it is measured on the side of the receiver where the attenuation of the electrical signal is highest (Fig. 5).

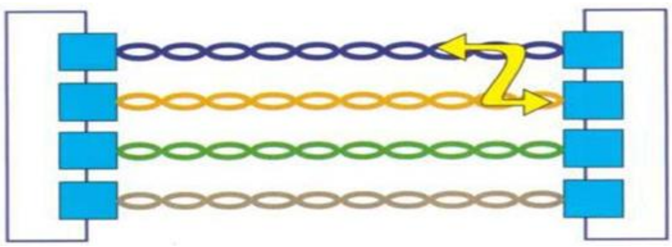

Fig. 5 Far End Attenuation principle

Source: [22]

Attenuation – is given by determining the size of electrical signal losses in dB. The signal with increasing cable length weakens due to the physical properties of the metallic cable. In addition to the cable length, Attenuation is directly proportional to the transmission frequency.

Delay Skew – is given by the time it takes for the electrical signal to pass from the transmitter to the receiver. It is measured in nanoseconds [22].

METHODOLOGY AND RESULTS OF CABLE TESTING

To ensure quality, the cables are subjected to tests after the production process, during which their low-frequency and high-frequency electrical parameters are checked. The measurement of that parameter was performed using a circuit analyser. The individual pairs of the tested cable were consequently connected to the selectors, in order to control all electrical parameters. Figure 6 shows the wiring diagram for measuring electrical parameters.

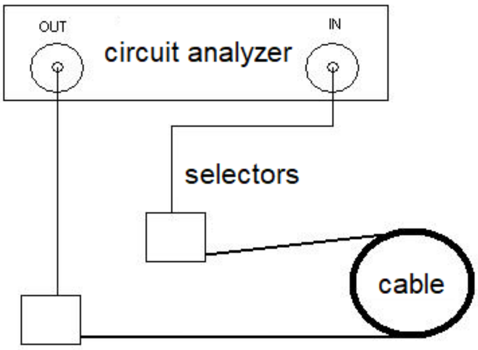

Fig. 6 Wiring diagram for measuring electrical parameters

For the purposes of this research, the UC900 SS23 Cat.7 cable was tested, which contains four pairs of conductors in the following colours (see Fig. 7):
Pair 1: white – blue
Pair 2: white – orange
Pair 3: white – brown
Pair 4: white – green.

Fig. 7 UC900 SS23 Cat.7 cable composition

Source: [21]

Each of these pairs is tested separately. If one pair shows critical values, the whole cable is no longer usable and must be scrapped. The following graphs in Fig. 8 show the testing of the Return Loss (RL) parameter in dB units which indicates how much of the signal is lost by reflection at the cable damage location. The test starts at 1 MHz and continues up to 600 MHz. The curve at the bottom of the graph shows the limit value given by ISO 11801, depending on the frequency.

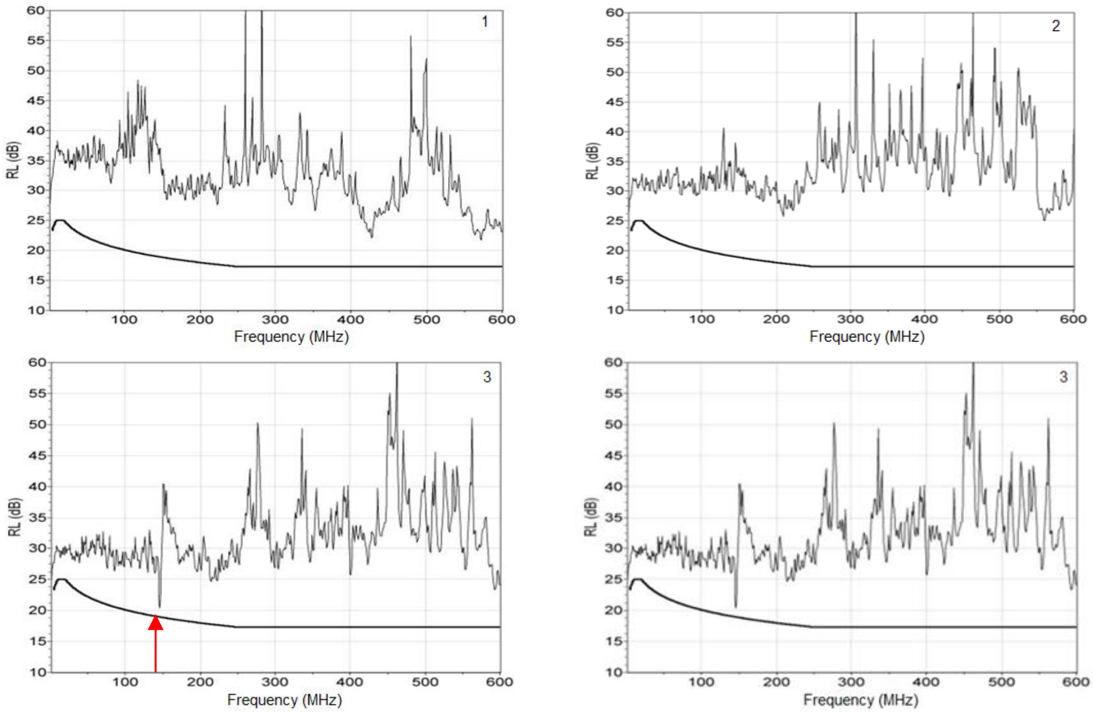

Fig. 8 Testing the cable pairs numbered as indicated in the upper right corner

Figure 8-3, which corresponds to the white-brown pair test, clearly shows a significant peak decrease at 145 MHz (indicated by arrow) with an RL value of 20.3 dB. This peak is very close to the permissible limit and during production, it is not acceptable to send such cables for the following operations, as there is a high risk that the RL parameter will cross the tolerance limit after further cable processing.

Group pairer diagnostics

The production of data cables consists of several operations that could cause critical values of the return loss parameter. If the error were caused by the drawing or annealing process, all pairs of data cables would reach critical values.

Since the error signal was only detected for pair number 3 (white-brown), it is clear that this error occurs in the group pairing process, specifically in pair number 102, model GTSD 560N-4-4M. Therefore, this pairer was chosen as the object of vibrodiagnostic measurement.

The basic technical parameters of this pairer are as follows:

- Brand: Setic
- Type: group pairer
- Model: GTSD 560N-4-4M
- Year of production: 2005
- Power supply: 440 V/60 Hz
- Number of pairs: 2
- Wire diameter range: 0.4-0.8 mm
- Maximum production capacity: 3000 turns/min
- Maximum unwinding speed: 40 m/min

- Engine power: 20.6 kW.

The analysis of the design and operation of the machine leads to the formulation of the hypothesis that the error may be caused by the difference between the unwinding speed and the pulling of the cable during pairing. The unevenness of these speeds can cause the cable to stretch excessively, which can cause failures in its metal core. Therefore, bearing housings were chosen as the subject of vibrodiagnostic measurement, as bearing wear leads to its jamming, which may be the cause of the critical value of the monitored parameter.

The Cmms Checker HW V300 inspection device (Fig. 9) was used to perform the vibrodiagnostic measurement. The measuring nodes were determined on the left and right bearing housing, in the horizontal and vertical directions. The accelerometer was attached to the bearing housings by means of a magnet, always in the middle of the housekeeping. The measurement was performed at different unwinding speeds, from 0 $m.min^{-1}$ to 40 $m.min^{-1}$ with a change of 10 $m.min^{-1}$.

Fig. 9 CMMS Checker

Fig. 10 presents the measured values on bearings Nos. 1 and 2. The comparison of the measured values shows that the vibration parameters are significantly higher in both measured axes (horizontal and vertical) on bearing house No. 2. Since both bearing housings are loaded in the same way, higher values of velocity and acceleration of vibrations are caused by that bearing. The decision was to replace that bearing.

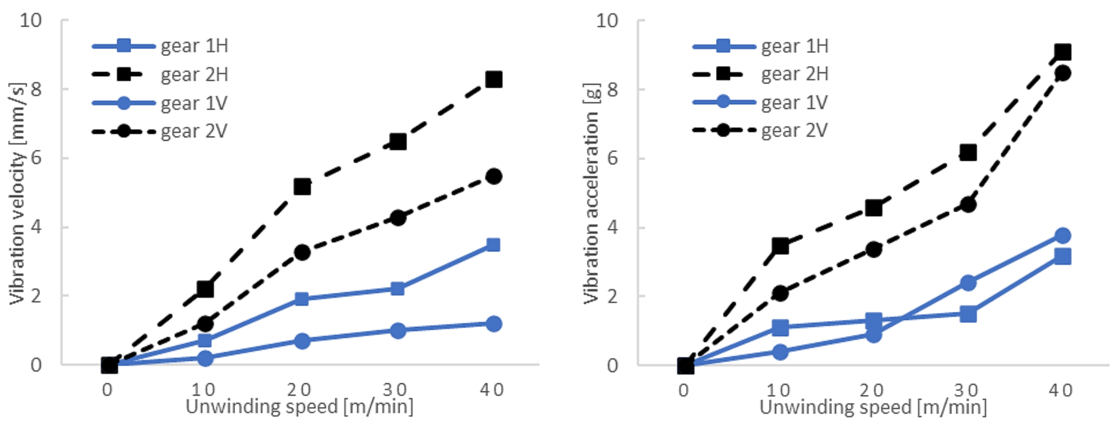

Fig. 10 Vibration velocity (left) and acceleration (right) values on bearings Nos. 1 and 2; H - horizontal; V - vertical

After replacing, checking the vibration parameters, it was still necessary to verify whether the maintenance of the group pairer helped to solve the problem with the return parameter.
After maintenance and replacement of the bearing, a verification vibrodiagnostic measurement on the bearing No. 2 was performed. As can be seen in Fig. 11, the values of the vibration parameters reached convenient values in both the horizontal and vertical directions that are significantly lower than in the measurement before maintenance, as presented in Fig. 11.

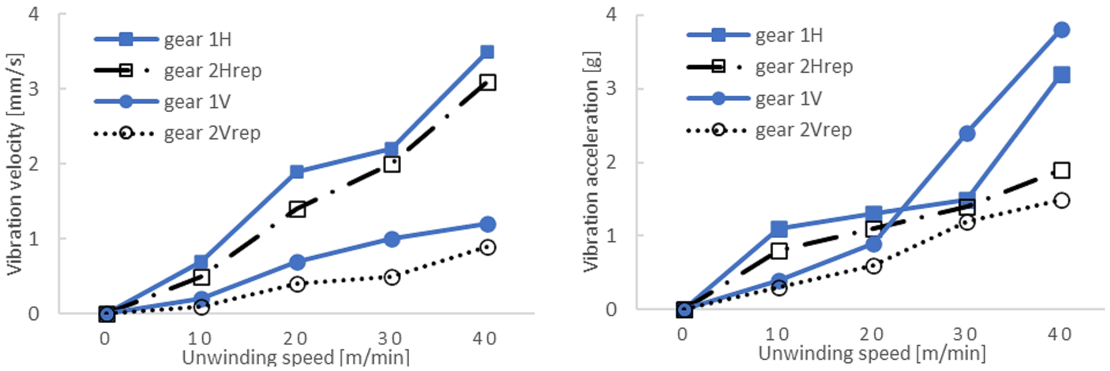

Fig. 11 Vibration velocity (left) and acceleration (right) values on bearings Nos. 1 and 2 (after repair; denoted "rep"); H - horizontal; V - vertical

Thus, the following step was control measurement of electrical characteristics, presented in Fig. 12. As can be seen from the measured course, the RL parameter of twisted cable pair No. 3 reached the standard values throughout the whole measured range.
Therefore, it can be concluded that the problem was caused by a group pairer bearing failure. Subsequent maintenance eliminated this problem, which was confirmed by the performed vibrodiagnostic measurements and measurements of electrical parameters.

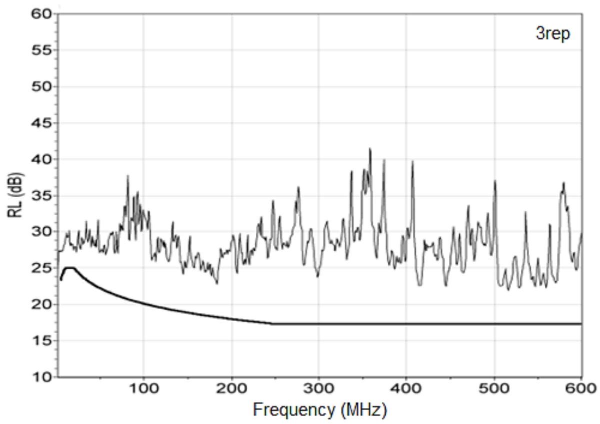

Fig. 12 Cable pair No. 3 test after maintenance

CONCLUSION

By analyzing the solved problem with the properties of pair no. 3, after evaluating the measurements of the transmission properties of the cables, the vibrations of the bearing housing of the group cable pairer were selected as the subject of the diagnostic measurement. The measurement of vibrations on the bearing housings clearly showed increased values of vibrations on the bearing housing no. 2. In comparison with deposit house no. 1 vibrations reached at peak values eminently times higher values of speed and acceleration at house no. 2. Therefore, the bearing was replaced based on the detected condition and the group pairer was pretermly servised.

After maintenance, a verification vibrodiagnostic measurement was performed on the left bearing housing. The measurement confirmed the elimination of the vibration problem. Vibration velocity and acceleration values have returned to standard levels. To verify the elimination of the RL parameter (return losses), measurements of the electrical properties of the manufactured cable were performed. The measurement courses of the RL parameter prove the elimination of the problem of imminent exceeding of the critical value of the monitored parameter.

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